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Optimizing baby corn growth, yield and quality with plant growth regulator (PGR) and NPK fertilizer

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ABSTRACT

Purpose: Using plant growth regulators (PGR) and nutrients in a standard way can help plants grow better. That's why we did this experiment to see how PGR and NPK fertilizer affected the growth, yield, and quality of baby corn. **Research method:** The split plot experiment employed plant growth regulator in the main plot and NPK fertilizer in the subplot. The test had four different PGRs: control (P_1), mepiquat chloride 200 ppm (P_2), naphthalene acetic acid (NAA) 40 ppm (P_3), and gibberellic acid (GA_3) 100 ppm (P_4). It also had four different NPK (Urea-TSP-MoP) fertilizer levels: 150-90-75 (F_1), 180-105-90 (F_2), 210-120-105 (F_3), and 240-135-120 (F_4) kg ha^{-1}. **Findings:** From the results, the interaction effect showed that P_4 in combination with F_4 produced the highest yield parameters, including cob length with husk (23.11 cm), diameter with husk (3.46 cm), diameter without husk (2.95 cm), weight without husk (55.29 g), cob plant^{-1} (3.67), and yield without husk (4.41 t ha^{-1}). The maximum starch (8.15%) was achieved when P_2 was combined with F_4, while the maximum protein (5.56%) was gained when P_2 was combined with F_3. **Research limitations:** The experiment is conducted in a single season and single location, hence multilocation and multi-years' trial should be conducted before recommending these results to the farmers. **Originality/Value:** Based on the results it can be conclude that spraying GA3 100 ppm along with NPK fertilizer (240–135–120 kg ha^{-1}) is thought to be a good way to improve baby corn growth, yield, and quality.

INTRODUCTION

Maize (*Zea mays* L.), a crop that is classed as both a grain and a vegetable, is the third most significant food crop, behind rice and wheat. An average of less than 1.0 t ha^{-1} for many generations until 1992 was exceeded by 7.46 t ha^{-1} in 2016–17 in Bangladesh due to the introduction of hybrids and the implementation of alternative crop management techniques (DAE, 2017). Between 2019 and 2020, Bangladesh produced approximately 4 million metric tons of maize (BBS, 2020). In Bangladesh, the majority of the country's land is currently used for the cultivation of maize (Asaduzzaman et al., 2023). Rangpur division holds the largest share of these districts, followed by Khulna and Rajshahi (Pandey & Koirala, 2017). Fresh or cooked, the maize ear can be enjoyed as a vegetable. It is harvested when it is very young, around 1–1.5 cm broad and 10–12 cm long, and before the silks has fully emerged or are just beginning to do so (Brewbaker & Martin, 2015).

It has a popular name as “baby corn” worldwide in the market. The baby corn could be a good source of fat protein, carbohydrate, calcium, phosphorus and ascorbic acid in our diet (Thavaprakaash et al., 2005). Like other baby corn exporting countries of the world, Bangladesh also can be a major baby corn exporter. Both proper crop management practices and the application of growth regulators, such as Gibberellin, can significantly increase crop yield and quality, which is important for the yield of agricultural products such as maize and soybeans that can be consumed as both grain and vegetable, including baby corn (Huang et al., 2021). Plant growth regulators (PGRs) are substances, either manufactured or naturally occurring, that influence the metabolic or developmental processes of higher plants, usually at low concentrations. They are usually not phytotoxic and have no nutritional value. The term "plant growth substances" can be used (Rademacher, 2015). PGRs are chemical molecules that improve the source-sink connection, increase photo-assimilate translocation, and aid in the generation of effective flowers, fruits, and seeds (Asad et al., 2023). The effects of gibberellin acid (GA3) on plant growth have been documented by numerous experts. Several research on various crops have demonstrated that by altering critical physiological processes, exogenous GA3 treatment can increase crop productivity (Gondaliya et al., 2023; El-Tohamy et al., 2023). Naphthalene acetic acid (NAA), an auxin, enhances growth properties and stimulates the reproductive phase by encouraging vegetative development through active cell division and expansion (Elmongy et al., 2018). Mepiquat chloride is a growth retardant that lowers plant height, which enhances yield by facilitating the efficient transfer of photosynthesis from source to sink since the distance between source and sink is shortened (Luo & Tang, 2023). Enhancing crop yield and quality in various field crops can be achieved through the use of growth regulators as foliar spray at the appropriate crop growth stage and at the ideal concentration (Nagasubramaniam et al., 2007). Gibberellin (GA) is the second class of plant hormones that controls cell elongation and division in plant shoots (Tong et al., 2014). They have been discovered to increase the formation of ribonucleic acid and protein in plant cells. Fall buds will remain dormant until the next spring in colder climates due to harsh cold (Fadón et al., 2020). Spraying plants with different amounts of gibberellic acid during the stage of 3–4 leaf growth boosts soybean yield components and seed production (Azizi et al., 2012). Proper application of PGR, like gibberellins, can raise yield and quality, but it is equally essential to ensure this crop receive adequate amounts of primary nutrients such as phosphorus, nitrogen, and potassium for optimal growth and productivity (Bons et al., 2015). It has been established that the three main fundamental nutrients: N, P, and K are necessary inputs for maintaining baby corn output and improving its quality (Yadav et al., 2018) Nucleic acids and proteins include nitrogen, and development suffers when nitrogen levels fall below optimal levels (Ding et al., 2021). For optimal maize growth, it must be available in adequate quantities throughout the growing season (Haque et al., 2001). In addition to acting as an active zone for absorbing carbon dioxide, phosphorus is essential for energy transformation and photosynthate assimilation into other metabolites (Vengavasi et al., 2021). As with other processes, potassium is necessary for the activation of enzymes, photosynthesis, protein synthesis, stomatal movement, osmoregulation, cation-anion balance, stress tolerance, energy transfer and phloem transport (Gul et al., 2015). Growing and producing baby corn crops can be greatly impacted by the application of fertilizers such as potassium, phosphorus, and nitrogen, as well as PGRs (Waqas et al., 2017). In particular, growth regulator and fertilizer management application must be standardized in order to raise the growth, quality, and yield, aspects of this crop (Rademacher, 2015). PGRs have the ability to boost crop productivity in the face of environmental challenges (Quamruzzaman et al., 2021). They have the ability to alter growth and development processes, leading in larger yields, better grain quality, and simpler harvesting (Passioura & Angus, 2010). Plant growth regulators and nutrient levels have a role in nutrient uptake and growth. That's why this study is very important for scientifically explaining that PGRs and NPK are helpful in baby corn production and individual or combined effect of PGRs and NPK fertilizers are very crucial. This research may lead to more improved baby corn production in the future.

MATERIALS AND METHODS

Experimental site and design

From December 2018 to April 2019, the experiment was conducted at Bangladesh Agricultural University's Agronomy Field Laboratory in Mymensingh. At an average height of eighteen meters, the location of the trial area was at latitude $24^0$75'N and longitude $90^0$50'E. It is found in the Sonatala series of the Old Brahmaputra Floodplain, which is a part of the Agro-Ecological Zone's (AEZ-9) non-calcareous dark grey riverbank soil (UNDP & FAO, 1988) (Table 1). Figure 1 indicates the agroclimatic conditions during the research period. The experiment was set up in a split plot design due to manage the study easily containing three replications. In the main plot, plant growth regulator was used, while in the subplot, NPK fertilizer was used. There were sixteen different treatments. Three times each treatment set was duplicated. Each block was subdivided into 16-unit plots, with treatment combinations assigned at the split. As a result, there were 48-unit plots in total. Each unit plot was 15 m^2 in size. The distance between two neighboring plots was 50 cm, replication to replication was 100 cm.

Experimental factors and treatments

The experiment comprised four plant growth regulators and four fertilizer rates with three replications as below: Factor A: Plant growth regulator (applied at 35 & 55 days after sowing (DAS), P_1=No plant growth regulator (Water only), P_2=Mepiquat chloride 200 ppm, P_3=Naphthalene acetic acid (NAA) 40 ppm, P_4=Gibberellic acid (GA_3) 100 ppm (FRG, 2012). Factor B: NPK fertilizer (Urea-TSP-MoP), F_1=150-90-75 kg ha^{-1}, F_2=180-105-90 kg ha^{-1}, F_3=210-120-105 kg ha^{-1}, F_4=240-135-120 kg ha^{-1} (FRG, 2012). At 35 DAT, the plants were typically in the six-leaf stage, and at 55 DAT, they were in the tasseling stage.

Planting method

Seed to seed distance was 25 cm and row to row spacing was 50 cm. Planting depth was 2.5 cm. One seed per hole was placed.

Table 1. Physical and chemical characteristics of the experimental field.

Physical and chemical properties of soil											
Physical						Chemical					
Sand (mm)	Silt (mm)	Clay (mm)	Textured	Bulk density	Porosity (%)	pH	OM (%)	N (%)	P (ppm)	K (meq%)	S (ppm)
32	60	08	Silt loam	1.35	46.67	6.50	1.19	0.10	16.72	0.12	14.2

Results of the original soil sample's mechanical examination performed at BAU, Mymensingh's Department of Soil Science. Where, OM= Organic Matter, N= Nitrogen, P= Phosphorous, K= Potassium, S= Sulphur.

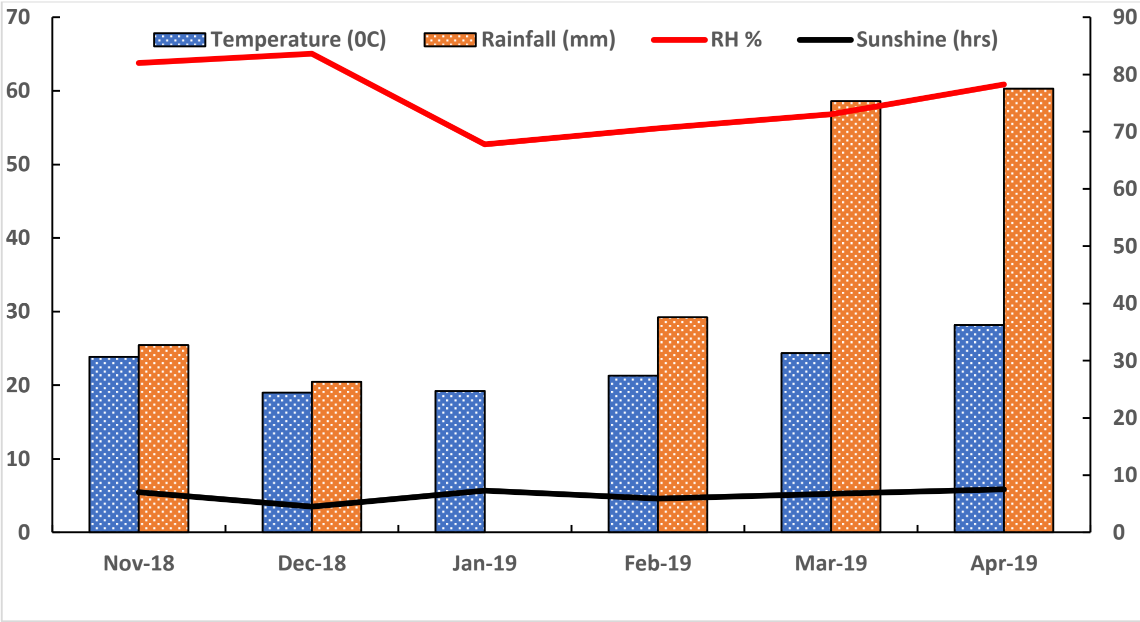

Fig. 1. Temperature, relative humidity, sunlight hours, and rainfall distribution monthly at the experimental location during the crop growing period.

Fertilizer application

Before sowing to plots as per treatment, half of urea and the entire amount of TSP and MoP as nitrogen, phosphorus, and potassium sources, 2.5 kg cowdung, 0.14 kg ha^{-1} $ZnSo_4$, 2 kg ha^{-1} gypsum were applied (24 December, 2018) at the final land preparation. As per treatment, another dose of urea was applied on 35 DAS (29 January, 2019). The micronutrient fertilizers were used according to the Agro-Ecological Zone (AEZ-9). Fertilizers were frequently broadcast throughout the soil surface, either as a top dressing during the growing season or as a base application prior to planting. Various fertilizer types were sometimes applied in layers based on the crop's particular nutrient requirements.

Preparation of PGR solution and application

For preparation of stock solution of Napthalene acetic acid (NAA) (ACI Fertilizer, Tejgaon, Dhaka, Bangladesh) 0.1g powder was completely dissolved in 1 litre water. This is the solution that gave the concentration of 100 ppm. From the stock solution, NAA 40 ppm solution was prepared by diluting. For preparation of stock solution of Gibberelic Acid (GA3) (ACI Fertilizer, Tejgaon, Dhaka, Bangladesh) 0.1g powder was completely dissolved in 1 litre water. This is the solution that gave the concentration of 100 ppm. For preparation of stock solution of mepiquat chloride (ACI Fertilizer, Tejgaon, Dhaka, Bangladesh), 0.1 ml mepiquat liquid was completely dissolved in 1 litre water. This is the solution that gave the concentration of 1000 ppm. From the stock solution, mepiquat chloride 200 ppm solution was prepared by diluting. At 35 and 55 days after sowing PGRs, NAA 40 ppm, mepiquat chloride 200 ppm, and GA3 100 ppm as per treatment were sprayed using a low volume sprayer (29 January, 19 February, 2019, respectively).

Irrigation

Irrigation was applied to the crop as needed, based on the soil's moisture level. Throughout the crop growing phase, careful attention was devoted to ensuring the availability of moisture in the soil. After 20 DAS, the first irrigation was performed, followed by another at 40 DAS. Irrigation was done 6 to 8 times.

Harvesting

After two to three days of silk emergence, the green cobs were removed from each net plot on alternating days, leaving the border and penultimate rows intact (Šimášková et al., 2022). At each plucking, the weight of these immature harvested cobs from each plot was recorded and represented in grams (g). Picking took place primarily in the morning and evening, when the ambient temperature was cooler and the moisture content of the baby corn was higher. The green fodder was collected after the green cobs were eliminated from every plant in the plot throughout numerous pickings, and the biomass of green fodder from each plot was quantified using a balance and expressed in metric ton per hectare.

Growth characters

Plant height

The height of five tagged plants in each plot was measured from the ground level to collar of the upper most fully opened leaf up to the flowering and from ground level to the base of tassel after flowering. Average of five plants was worked out to get the mean plant height in centimeters (cm).

Number of leaves plant^{-1}

Leaf number of the five selected plants was recorded.

Leaf length

The five randomly selected plants leave length for each plot was recorded separately with the help of a meter scale. Then average height of leaves plant^{-1} was worked out in cm.

Leaf width

The above-mentioned selected plants leave used for measurement of width with the help of meter scale at three places i.e., at the base, the center, at upper portion and the mean width for individual plant was determined in cm.

Chlorophyll content (SPAD value)

The amount of chlorophyll in the leaves can be used as a proxy for crop nitrogen status. At 90 days after emergence, SPAD readings were collected with a portable SPAD meter (model SPAD-502, Minolta crop, Ramsey, NJ). To record SPAD values, three additional completely grown leaves were chosen. The equipment measures red light transmission at 650 nm, where chlorophyll absorbs light, and infrared light transmission at 940 nm, when no absorption occurs. The chlorophyll meter reading has been positively correlated with destructive chlorophyll measurements in many crop species (Zhu *et al.* 2012) and considered as a useful indicator of need of N top dressing during the crop growth. The sensor calculates a SPAD value that is well associated with chlorophyll concentration based on these two transmission measurements.

Root, stem, leaf dry weight plant^{-1} (g)

Five plants were randomly selected in the sampling row. They were cut very close to the ground level for the determination of root, stem and leaf dry weight. The sampled plants were separated into leaves, stem and root. The sampled plants were separated into root, stem, and leaves. The samples were washed with water and dried in an electric oven for 72 hours maintaining a constant temperature of 70°C. After drying, weight of each sample was recorded. Dry weight of partitioning parts (root, stem, leaves) was expressed in g plant^{-1}.

Yield and yield components

Number of cobs plant^{-1}

The number of young cobs gathered from each plot's five tagged plants was separately recorded, and the average number of baby corn cobs per plant was calculated.

Fresh weight plant^{-1}

For the determination of fresh weight of plants, five tagged plants from each plot were cut very close to the ground level, their weights were recorded, and the average weight plant^{-1} was calculated.

Dry weight plant^{-1}

After recording fresh weight, plants were sun dried for 3-4 days. Then their dry weights were recorded and the average dry weight per plant was calculated.

Cob length

The length of ten randomly selected immature cobs from each plot's harvested lot were measured with and without husk from top to bottom on a meter scale, and the mean length per cob with and without husk was calculated in centimeters (cm).

Cob diameter

The same ten randomly selected cobs that were used to measure length were also used to measure diameter. With the use of a vernier caliper, the diameter of cobs with and without husk was measured at three locations: the base, the center, and the pointed end of the cob, and then the average diameter for each cob were calculated.

Cob weight with husk

The average weight of ten young baby corn cobs with husk was determined and given in grams based on the total weight of ten young baby corn cobs used for length and girth measurements.

Cob weight without husk

The average weight of ten young baby corn cobs without husk was computed and represented in grams based on the total weight of ten young baby corn cobs used for length and girth measurements.

Green fodder yield

After the plucking of young cobs in all net plots was completed, the baby corn plants were cut at ground level with sickles and weighed to calculate the green fodder production in t ha^{-1}. The green fodder yield of the matching net plot includes husk recovered from young cobs in each plot.

Cob yield with husk

In all pickings, the total weight of young cobs with husk taken from each net plot was recorded in kilograms and then translated to t ha^{-1} on a hectare basis.

Cob yield without husk

In all pickings, the total weight of young cobs without husk taken from each net plot was recorded in kilograms and then translated to t ha^{-1} on a hectare basis.

Quality parameter

Determination of starch and protein content

Fresh corn's starch (%) content was measured using the methods outlined by Hodge and Hofreiter (1962). Similarly, the Micro-Kjeldahl method was used to measure the protein (%) contents. Samples of the cob, leaf, and stem were taken from every plot. The samples were manual drying and cleaning. A grinding mill with 60 mesh sieves was used to grind the oven-dried samples. After that, the samples were packaged into polythene bags and placed in a desiccator to await further chemical analysis and protein quantification. The Department of Biochemistry and Molecular Biology of Bangladesh Agricultural University measured the protein content (%) using the Micro-Kjeldahl method as follows: Ground cob, leaf and stem sample amounting 0.5 g was digested with 8 ml H_2SO_4-H_2O_2 digestion mixture (6 ml H_2SO_4 and 2ml H_2O_2) and 1g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se=10:1:0.1 for 30 mins at 120^0C followed by 70-90 mins at 360-380^0C. In 100 milliliters of deionized water, the digestion solution was dissolved. Using the modified Kjeldahl method, which involves distilling with 10 N NaOH and titrating the distillate trapped in 2% H_3BO_3 with 0.05 N H_2S0_4, a 25 ml digests dilution was obtained in order to assess the N concentration (Bremner & Mulvaney, 1982). For determining % protein, the amount of nitrogen was multiplied by conversion factor (6.25).

Statistical analysis

The acquired data were properly assembled and tabulated, and statistical analysis was performed on them. With the use of the computer application R-studio, the analysis of variance (ANOVA) approach was applied to the data, and the Duncan's Multiple Range Test was used to determine the mean differences (Gomez & Gemez, 1984).

RESULTS

Growth Parameters

Effect of PGR

The effect of PGRs showed significant effect on plant height, chlorophyll content, leaf number, leaf width, leaf length, leaf dry weight stem dry weight, and root dry weight was non-significant (Fig. 2A & 3A). Tallest plant height **(**126.22 cm), maximum leaf no (12.29), leaf length (39.19 cm), highest leaf width (7.16 cm), chlorophyll content (SPAD value) (39.13), highest stem dry weight (36.6 g) was recorded at P_4 (Gibberelic Acid 100 ppm). Highest root dry weight (11.20 g), and leaf dry weight (11.9 g) was observed in P_1 (water only) and P_3 (Naphthalene acetic acid (NAA) 40 ppm) respectively which were statistically similar with P_4 (Gibberelic Acid 100 ppm). The smaller plant height (115.14 cm), minimum leaf number (10.27), leaf length (33.81 cm), leaf width (5.83 cm), chlorophyll content (33.26), stem dry weight (32.86 g), leaf dry weight (9.38 g) was observed in P_1 (water only) and root dry weight (10.31 g) was observed in P_4 (Gibberellic Acid 100 ppm) which was statistically similar with P_1 (water only) (Fig. 2B & 3A).

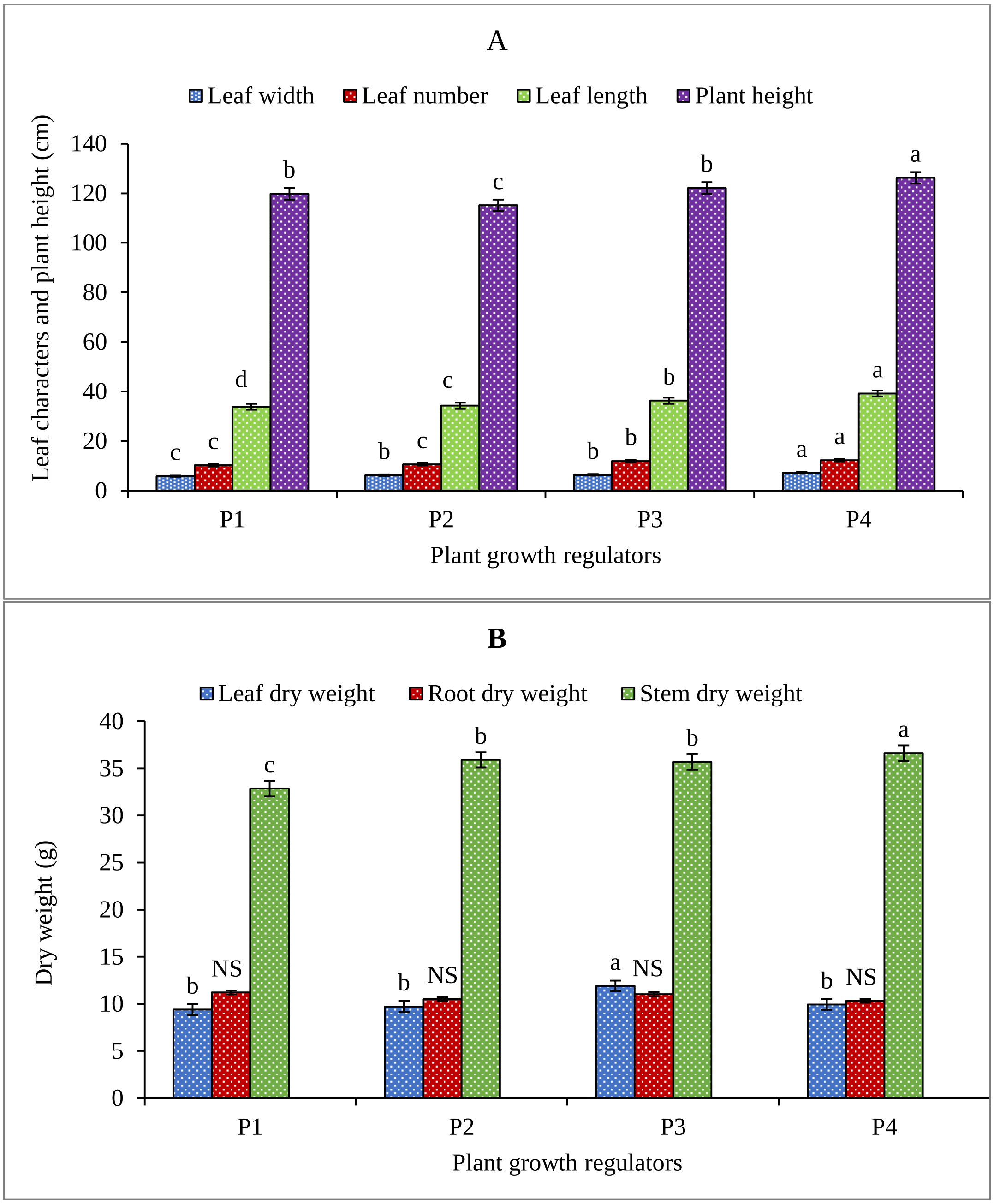

Fig. 2. Effect of plant growth regulator on leaf characters' plant height (A) dry weight (B) of baby corn.
The means that have the same letters are not substantially different. P_1=Water only, P_2=Mepiquat chloride 200 ppm, P_3=Naphthalene Acetic Acid (NAA) 40 ppm, P_4=Gibberellic acid (GA_3) 100 ppm.

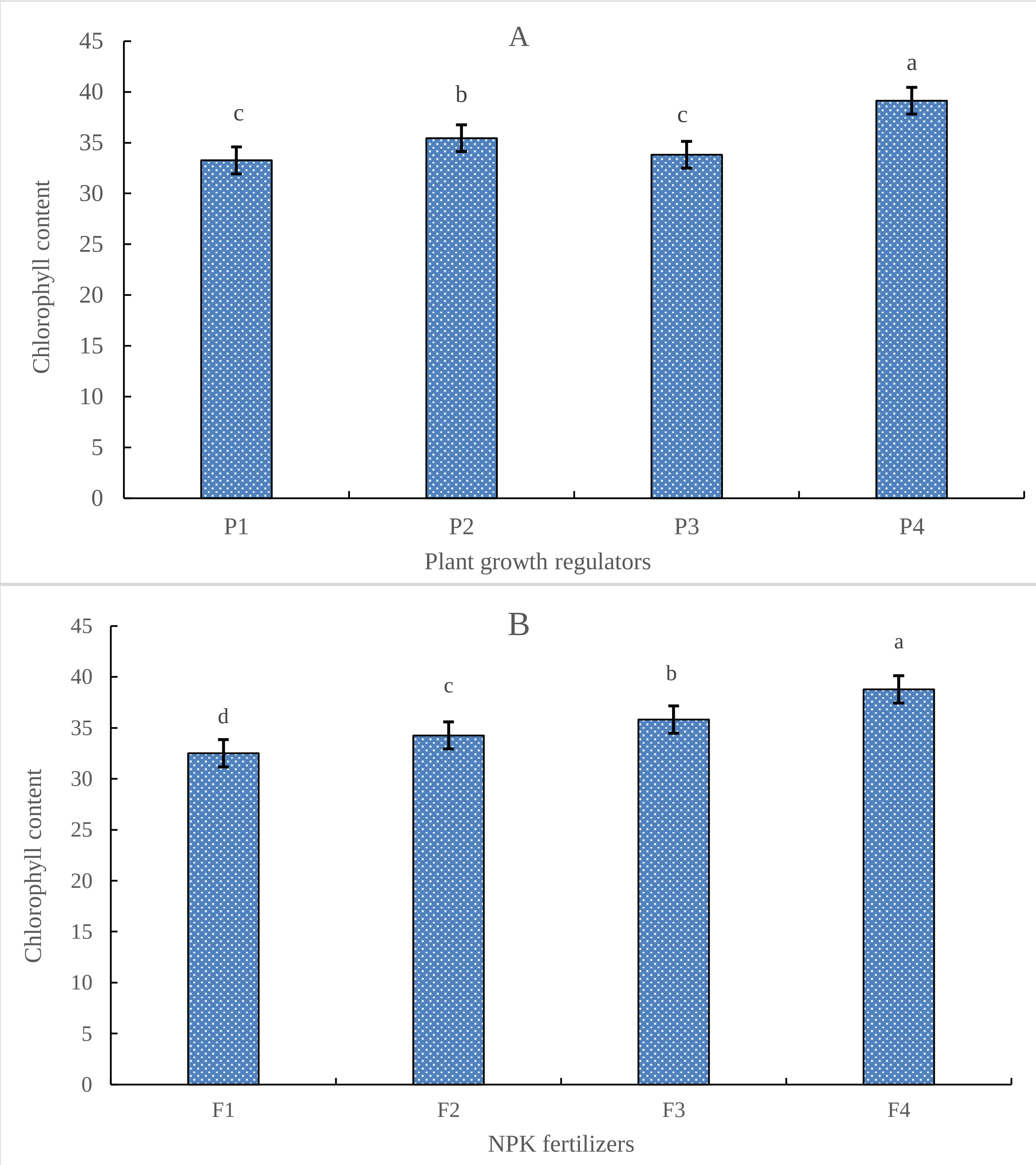

Fig. 3. Effects of PGRs (A) and NPK fertilizers (B) on baby corn's leaf chlorophyll content.
The means that have the same letters are not substantially different. P_1=Water only, P_2=Mepiquat chloride 200 ppm, P_3=Naphthalene Acetic Acid (NAA) 40 ppm, P_4=Gibberellic acid (GA_3) 100 ppm.

Effect of NPK fertilizer level

Level of NPK fertilizers had significant effect on plant height, chlorophyll content, leaf number, leaf width, leaf length, leaf dry weight, root dry weight; stem dry weight, (Fig. 4A & 3B). Highest plant height (122.42 cm), maximum leaf number (11.84), stem dry weight (36.86 g) was recorded in F_3 (210-120-105 kg ha^{-1}). Maximum leaf length (39.91 cm), leaf width (7.23 cm), chlorophyll content (38.78) was observed in F_4 (240-135-120 kg ha^{-1}) which was statistically similar with F_3 (210-120-105 kg ha^{-1}). Maximum root dry weight (11.73 g) and leaf dry weight (10.75 g) was recorded in F_2 (180-105-90 kg ha^{-1}) which was followed by F_3 (210-120-105 kg ha^{-1}). The lowest plant height (117.45 cm), the minimum leaves (10.78), leaf length (33.47 cm), leaf width (6.00 cm), chlorophyll content (32.51), root dry weight (9.23 g), leaf dry weight (9.38 g), stem dry weight (33.86 g) was found in F_1 (150-90-75 kg ha^{-1}) (Fig. 4B & 3B).

Impact of PGRs and NPK fertilizer levels work together

The result revealed that plant height, chlorophyll content, leaf number, leaf width, leaf length, stem dry weight, leaf dry weight, was significantly affected by interaction of PGRs and NPK fertilizer levels. The highest plant height (119 cm) was recorded in interaction of water × 210-120-105 kg ha^{-1} and the lowest one (105.45 cm) was recorded in interaction of water × 150-90-75 kg ha^{-1} (Table 2). The highest leaf number (13.22) was recorded in interaction of Naphthalene acetic acid (NAA) 40 ppm × 210-120-105 kg ha^{-1} and the lowest one (9.70) was recorded in interaction of water × 150-90-75 kg ha^{-1} (Table 2).

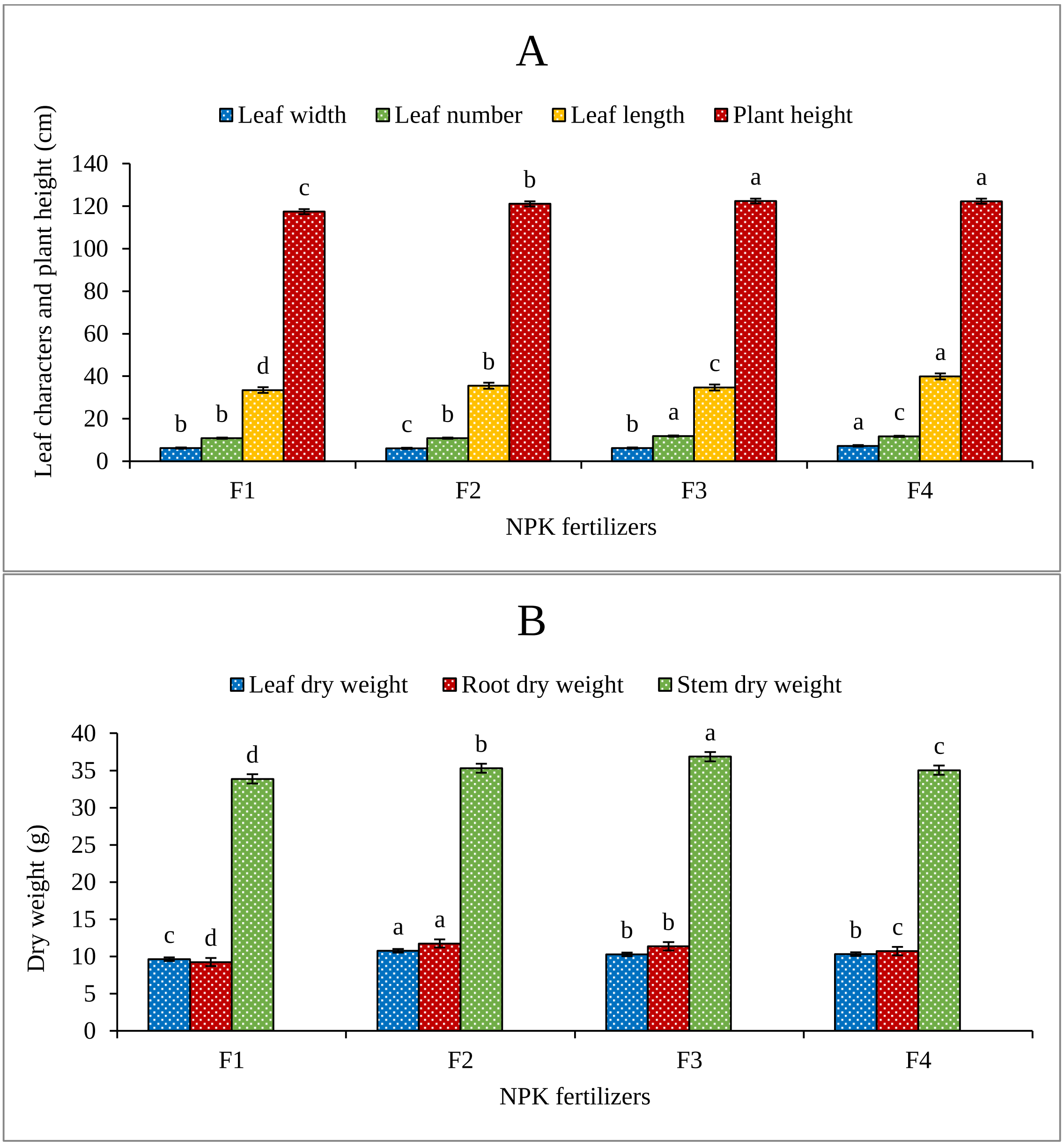

Fig. 4. Effect of NPK fertilizer on leaf characters' plant height (A) dry weight (B) of baby corn.
The means that have the same letters are not substantially different. F_1=150-90-75 kg ha^{-1}, F_2=180-105-90 kg ha^{-1}, F_3=210-120-105 kg ha^{-1}, F_4=240-135-120 kg ha^{-1}.

Table 2. Interaction effects of plant growth regulators and NPK fertilizer on plant characters of baby corn

Plant growth regulators: NPK fertilizer	Plant height (cm)	Leaf number	Leaf length (cm)	Leaf width (cm)	Chlorophyll content (Spade value)	Root dry weight (g)	Stem dry weight (g)	Leaf dry weight (g)
P1:F1	105.45d	9.70i	31.11d	5.35g	29.78e	8.99	33.69bc	9.17bc
P1:F2	120.33a-c	10.00hi	33.89cd	5.69e-g	33.92c-e	13.01	34.66bc	11.90b
P1:F3	129.00a	10.50gh	33.14cd	5.70e-g	32.55de	13.35	32.72bc	9.44bc
P1:F4	119.67a-c	10.89e-g	37.11bc	6.58b-d	36.47b-d	9.43	30.38c	7.02c
P2:F1	110.22cd	10.34gh	31.72d	5.56fg	32.21de	9.26	36.31a-c	9.24bc
P2:F2	117.56a-d	10.34gh	32.89cd	6.24c-f	32.34de	11.43	36.38a-c	10.12bc
P2:F3	117.78a-d	10.66fg	33.97cd	6.29c-f	38.72a-c	11.34	39.49ab	11.54b
P2:F4	119.78a-c	11.22c-f	38.47ab	6.69b-d	37.72a-c	9.95	31.43bc	7.99bc
P3:F1	125.89ab	11.11d-f	34.17cd	6.26c-f	32.01de	9.63	32.84bc	9.71bc
P3:F2	124.78ab	11.33c-e	36.50bc	5.93d-g	30.11e	11.16	31.43bc	11.29b
P3:F3	115.44b-d	13.22a	33.00cd	5.91d-g	34.30c-e	10.51	36.96a-c	10.45bc
P3:F4	122.45a-c	12.00b	41.50a	7.30b	38.63a-c	12.78	41.57a	16.17a
P4:F1	128.22ab	11.66b-d	36.86bc	7.04bc	35.72b-d	9.05	32.58bc	10.37bc
P4:F2	121.78a-c	11.74bc	38.64ab	6.48b-e	40.43ab	11.31	38.77ab	9.69bc
P4:F3	127.44ab	12.97a	38.69ab	6.78b-d	38.04a-c	10.22	38.28ab	9.63bc
P4:F4	127.45ab	12.78a	42.56a	8.33a	42.30a	10.66	36.80ab	10.00bc
$S\bar{x}$	1.65	0.26	0.86	0.19	0.94	0.35	0.82	0.5
Level of significance	*	**	*	*	*	NS	*	**
CV (%)	5.60	2.80	6.30	7.90	7.10	12.40	6.30	9.30

The means that have the same letters are not substantially different, * = Significant at 5 % level of probability, ** = Significant at 1% level of probability, NS = Not significant, P_1=Water only, P_2=Mepiquat chloride 200 ppm, P_3=Naphthalene acetic acid (NAA) 40 ppm, P_4=Gibberellic Acid (GA_3) 100 ppm, F_1=150-90-75 kg ha^{-1}, F_2=180-105-90 kg ha^{-1}, F_3=210-120-105 kg ha^{-1}, F_4=240-135-120 kg ha^{-1}.

The longest leaf length (42.56 cm) was recorded in interaction of Gibberellic acid (GA_3) 100 ppm × 240-135-120kg ha^{-1} which was similar with the interaction of Naphthalene Acetic Acid (NAA) 40 ppm × 240-135-120kg ha^{-1} and the lowest (31.17 cm) was recorded in interaction of water × 150-90-75 kg ha^{-1} (Table 2). The highest leaf width (8.33 cm) was seen in interaction of Gibberellic Acid (GA_3) 100 ppm × 240-135-120 kg ha^{-1} and the lowest one (5.35 cm) was seen in interaction of water × 150-90-75 kg ha^{-1} (Table 2). The highest chlorophyll content (42.30) was seen in interaction of Gibberellic Acid (GA_3) 100 ppm × 240-135-120kg ha^{-1} and the lowest one (29.78) was seen in interaction of water × 150-90-75 kg ha^{-1} (Table 2). The interaction effect of PGRs and NPK fertilizer levels showed non-significant effect on root dry weight. Numerically the highest value (13.35 g) was seen in interaction of water × 210-120-105 kg ha^{-1} and the lowest value (8.99 g) was seen in the interaction of water × 150-90-75 kg ha^{-1} (Table 2). The highest stem dry weight (41.57 g) was seen in interaction of Naphthalene Acetic Acid (NAA) 40 ppm × 240-135-120 kg ha^{-1} and the lowest one (30.38 g) was seen in interaction of water × 240-135-120 kg ha^{-1} (Table 2). The highest leaf dry weight (16.17 g) was seen in interaction of Naphthalene acetic acid (NAA) 40 ppm × 240-135-120 kg ha^{-1} and the lowest one (30.38 g) was seen in interaction of water × 240-135-120 kg ha^{-1} (Table 2).

Yield and yield contributing characters

Effect of PGRs

Number of cob $plant^{-1}$, fresh weight, dry weight $plant^{-1}$, cob length without husk, cob length with husk, cob diameter with husk, cob weight with husk, cob diameter without husk, cob weight without husk, green fodder yield, cob yield without husk, cob yield with husk was significantly affected by PGRs (Table 3 & Fig. 5A). The highest number of cob $plant^{-1}$ (3.25), fresh weight (109.81 g), dry weight (65.42 g), cob diameter with husk (3.32 cm), cob diameter without husk (2.76 cm), cob weight with husk (92.87 g), cob weight without husk (51.05 g), cob yield with husk (7.11 t ha^{-1}), cob yield without husk (4.02 t ha^{-1}) was observed in P_4 (Gibberellic acid (GA_3) 100 ppm). Highest cob length with husk (21.76 cm), cob length without husk (15.74 cm) was observed in P_2 (Mepiquat chloride 200 ppm) which was similar to P_4 (Gibberellic acid (GA_3) 100 ppm). The highest green fodder yield (26.52 t ha^{-1}) was recorded in P_3 (Naphthalene acetic acid (NAA) 40 ppm) which was statistically similar with P_4 (Gibberellic Acid (GA_3) 100 ppm). The lowest number of cob $plant^{-1}$ (2.58), cob length with husk (17.63 cm), cob length without husk (13.33 cm), cob diameter with husk (2.67 cm), cob diameter without husk (2.34 cm), cob weight (74.83 g), cob yield with husk (6.33 t ha^{-1}), cob weight without husk (39.27 g), cob yield without husk (3.20 t ha^{-1}) was found in P_1 (water only). Lowest fresh weight (89.00 g), dry weight $plant^{-1}$ (59.83 g), green fodder yield (23.24 t ha^{-1}) was observed in P_2 (Mepiquat chloride) which was statistically similar with P_1 (water only) (Table 3 & Fig. 5A).

Table 3. Effects of plant growth regulator on yield attributes and yield of baby corn.

Plant growth regulators	No. of cob $plant^{-1}$	Fresh weight $plant^{-1}$ (g)	Dry weight $plant^{-1}$ (g)	Cob length with husk (cm)	Cob length without husk (cm)	Cob diameter with husk (cm)	Cob diameter without husk (cm)	Cob weight with husk (g)	Cob weight without husk (g)	Green fodder yield (t ha^{-1})
P1	2.58b	98.58ab	60.60b	17.63b	13.33b	2.67b	2.34b	74.83c	39.27b	23.91b
P2	3.17a	89.00b	59.83b	21.76a	15.74a	3.13ab	2.57ab	88.57b	47.36a	23.24b
P3	2.92ab	94.89b	61.25b	19.39ab	14.07b	3.16a	2.59ab	86.79b	47.68a	26.52a
P4	3.25a	109.81a	65.42a	21.71a	13.75b	3.32a	2.76a	92.87a	51.05a	25.86a
$S\bar{x}$	0.15	4.38	1.25	1.00	0.53	0.14	0.08	3.86	2.50	0.78
Level of significance	*	*	*	*	*	*	*	**	**	**
CV (%)	5.80	12.50	9.10	13.40	9.40	5.40	12.00	2.20	11.70	3.40

The means that have the same letters are not substantially different, * = Significant at 5 % level of probability, ** = Significant at 1% level of probability, P_1=Water only, P_2=Mepiquat chloride 200 ppm, P_3=Naphthalene acetic acid (NAA) 40 ppm, P_4=Gibberellic Acid (GA_3) 100 ppm.

Table 4. Effects of NPK fertilizer on yield attributes and yield of baby corn.

NPK fertilizer	Number of cob $plant^{-1}$	Fresh weight $plant^{-1}$ (g)	Dry weight $plant^{-1}$ (g)	Cob length with husk (cm)	Cob length without husk (cm)	Cob diameter with husk (cm)	Cob diameter without husk (cm)	Cob weight with husk (g)	Cob weight without husk (g)	Green fodder yield (t ha^{-1})
F1	2.42c	98.08b	57.56b	18.96c	12.57c	2.82c	2.30b	76.61d	39.68b	23.98b
F2	2.83bc	99.50ab	53.61b	19.86b	14.11b	3.05b	2.59ab	85.54c	46.52a	25.28a
F3	3.25ab	100.92a	74.82a	20.03b	14.68ab	3.15ab	2.62ab	88.60b	48.63a	25.32a
F4	3.42a	93.78b	61.11ab	21.64a	15.53a	3.26a	2.74a	92.31a	50.53a	24.96a
$S\bar{x}$	0.22	1.54	4.61	0.56	0.62	0.09	0.10	3.35	2.37	0.31
Level of significance	**	*	*	**	**	**	**	**	**	**
CV (%)	10.40	8.80	5.40	5.20	8.70	6.40	5.80	8.30	10.00	3.90

The means that have the same letters are not substantially different, * = Significant at 5 % level of probability, ** = Significant at 1% level of probability, F_1=150-90-75 kg ha^{-1}, F_2=180-105-90 kg ha^{-1}, F_3=210-120-105 kg ha^{-1}, F_4=240-135-120 kg ha^{-1}.

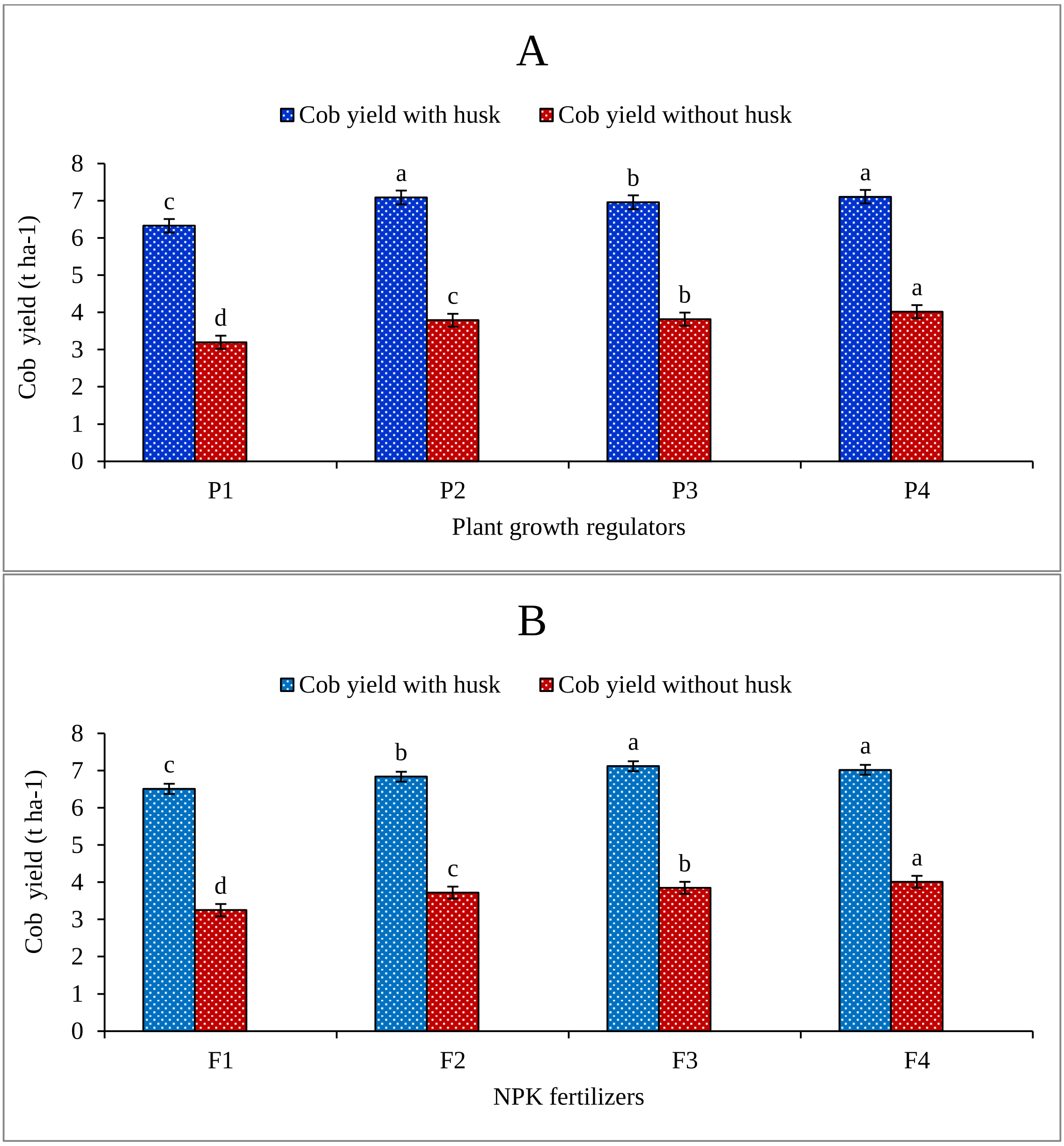

Fig. 5. Impact of PGRs (A) and NPK fertilizer (B) on baby corn yield measurements.The means that have the same letters are not substantially different. P_1=Water only, P_2=Mepiquat chloride 200 ppm, P_3=Naphthalene Acetic Acid (NAA) 40 ppm, P_4=Gibberellic acid (GA_3) 100 ppm, F_1=150-90-75 kg ha^{-1}, F_2=180-105-90 kg ha^{-1}, F_3=210-120-105 kg ha$^{-1,}$ F_4=240-135-120 kg ha^{-1}.

Effect of NPK fertilizer

NPK fertilizer had a significant impact on number of cob plant^{-1}, fresh weight plant^{-1}, dry weight plant^{-1}, cob length without husk, cob diameter with husk, cob length with husk, cob diameter without husk, cob weight without husk, cob weight with husk, green fodder yield, cob yield with husk, cob yield without husk (Table 4 & Fig. 5B). The highest number of cob plant^{-1} (3.42), cob length without husk (15.53 cm), cob diameter without husk (2.74 cm), cob weight with husk (92.31 g), cob diameter with husk (3.26 cm), cob weight without husk (50.53 g), cob yield without husk (4.01 t ha^{-1}) was recorded in F_4 (240-135-120 kg ha^{-1}) which was statistically similar with F_3 (210-120-105 kg ha^{-1}). The highest fresh weight (100.92 g), dry weight (74.82 g), green fodder yield (25.32 t ha^{-1}), cob yield with husk (7.12 t ha^{-1}) was observed in F_3 (210-120-105 kg ha^{-1}) which was statistically similar with F_4 (240-135-120 kg ha^{-1}). The highest cob length with husk (21.64 cm) was observed in F_2 (240-135-120 kg ha^{-1}) which was statistically similar with F_3 (210-120-105 kg ha^{-1}) and F_4 (240-135-120 kg ha^{-1}). Lowest number of cob plant^{-1} (2.42), cob length with husk (18.96 cm), cob weight without husk (39.68 g), cob length without husk (12.57 cm), cob yield with husk (6.51 t ha^{-1}), cob diameter with husk (2.82 cm), cob yield without husk (3.25 t ha^{-1}) , cob diameter without husk (2.30 cm), cob weight with husk (76.61 g), green fodder yield (23.24 t ha^{-1}) was recorded in F_1 (150-90-75 kg ha^{-1}). The lowest fresh weight (93.73 g) and lowest dry weight (53.61 g) was recorded in F_4 (240-135-120 kg ha^{-1}) and F_2 (180-105-90 kg ha$^{-1)}$ which was statistically similar with F_1 (150-90-75 kg ha^{-1}) (Table 4 & Fig. 5B).

PGRs and NPK fertilizer levels interact and influence the yield and characteristics related to yield of baby corn

Cob plant^{-1}, fresh weight, dry weight, cob length without husk, cob length with husk, cob diameter without husk, cob diameter with husk, cob weight without husk, cob weight with husk, cob yield without husk, cob yield with husk, and green fodder yield was significantly affected by interaction between PGRs and NPK fertilizer. The highest number of cob plant^{-1} (3.67) was observed in interaction of Gibberellic Acid 100 ppm × 240-135-120 kg ha^{-1} which was statistically similar with Gibberellic Acid 100 ppm × 210-120-105 kg ha^{-1}. The lowest number of cob plant^{-1} (2.00) was observed in interaction of water only ×150-90-75 kg ha^{-1} (Table 5). The highest fresh weight (125.62 g) was recorded in baby corn with Gibberellic acid 100 ppm × 150-90-75 kg ha^{-1} which was statistically similar with Naphthalene Acetic Acid (NAA) 40 ppm × 210-120-105 kg ha^{-1}. The lowest fresh weight (74.19 g) was recorded in interaction of water only × 240-135-120 kg ha^{-1} (Table 5). The highest dry weight (103.67 g) was recorded in interaction of Gibberellic acid 100 ppm × 210-120-105 kg ha^{-1} and the lowest dry weight (33.89 g) was recorded in interaction of Gibberellic acid 100 ppm × 180-105-90 kg ha^{-1} (Table 5). The highest cob length with husk (13.11 cm) was observed in interaction of Gibberellic acid 100 ppm × 240-135-120 kg ha^{-1} and the lowest cob length with husk (16.33 cm) was observed in interaction of water only × 150-90-75 kg ha^{-1} (Table 5). The longest cob length without husk (17.17 cm) was observed in interaction of Mepiquat chloride 200 ppm × 240-135-120 kg ha^{-1} and the lowest cob length without husk (11.55 cm) was obtained in interaction of water only × 150-90-75 kg ha^{-1} (Table 5). The highest Cob diameter with husk (3.46 cm) was observed in interaction of Gibberellic Acid 100 ppm × 240-135-120 kg ha^{-1} which was statistically similar with Naphthalene Acetic acid (NAA) 40ppm × 240-135-120 kg ha^{-1}. The lowest Cob diameter with husk (2.39 cm) was observed in interaction of water only × 150-90-75 kg ha^{-1} (Table 5). The highest cob diameter without husk (2.95 cm) was obtained in Gibberellic Acid 100 ppm × 240-135-120 kg ha^{-1}. The lowest cob diameter without husk (2.30 cm) was observed in water only × 150-90-75 kg ha^{-1} (Table 5). The maximum cob weight with husk (98.48 g) was obtained in interaction of Gibberellic Acid 100 ppm × 240-135-120 kg ha^{-1} which was statistically similar with Gibberellic Acid 100 ppm × 210-120-105 kg ha^{-1}. The minimum cob weight with husk (66.90 g) was observed in interaction of water only × 150-90-75 kg ha^{-1} (Table 5). The highest cob weight without husk (55.29 g) was observed in Gibberellic Acid 100 ppm × 240-135-120 kg ha^{-1}. The lowest cob weight without husk (33.45 g) was observed in interaction of water only × 150-90-75 kg ha^{-1} (Table 5). The highest cob yield with husk (7.31 t ha^{-1}) was recorded in Gibberellic Acid 100 ppm × 210-120-105 kg ha^{-1} which was statistically similar with Gibberellic Acid 100 ppm × 180-105-90 kg ha^{-1} and Mepiquat chloride 200 ppm × 210-120-105 kg ha^{-1}. The lowest Cob yield with husk (5.75 t ha^{-1}) was obtained in water only × 150-90-75 kg ha^{-1} (Table 5). The highest cob yield without husk (4.41 t ha^{-1}) was recorded in Gibberellic Acid 100 ppm × 210-120-105 kg ha^{-1}. The lowest Cob yield without husk (3.25 t ha^{-1}) was recorded in (water only

×150-90-75 kg ha^{-1} which was statistically similar with water only × 180-105-90 kg ha^{-1} (Table 5). The highest green fodder yield (26.73 t ha^{-1}) was recorded in interaction of Naphthalene Acetic Acid (NAA) 40 ppm × 210-120-105 kg ha^{-1} which was statistically similar with Naphthalene Acetic Acid (NAA) 40 ppm × 180-105-90 kg ha^{-1}. The lowest green fodder (22.34 t ha^{-1}) yield was recorded in interaction of water only × 150-90-75 kg ha^{-1} (Table 5).

Quality parameter

Effect of PGRs

The effect of plant growth regulator on Starch (%) content was significant. The highest starch content (8.12%) in P_2 (Mepiquat chloride 200 ppm) which was statistically similar with P_3 (Naphthalene Acitic Acid (NAA) 40 ppm) and P_4 and the lowest starch content (8.06%) was recorded with P_1 (water only) (Fig. 6A). Plant growth regulators favorably influenced the protein content of baby corn. Higher values of protein content (5.52%) obtained from the plants treated with P_2 (Mepiquat chloride 200 ppm) and the lowest protein content was recorded with P_1 (water only) (Fig. 6A).

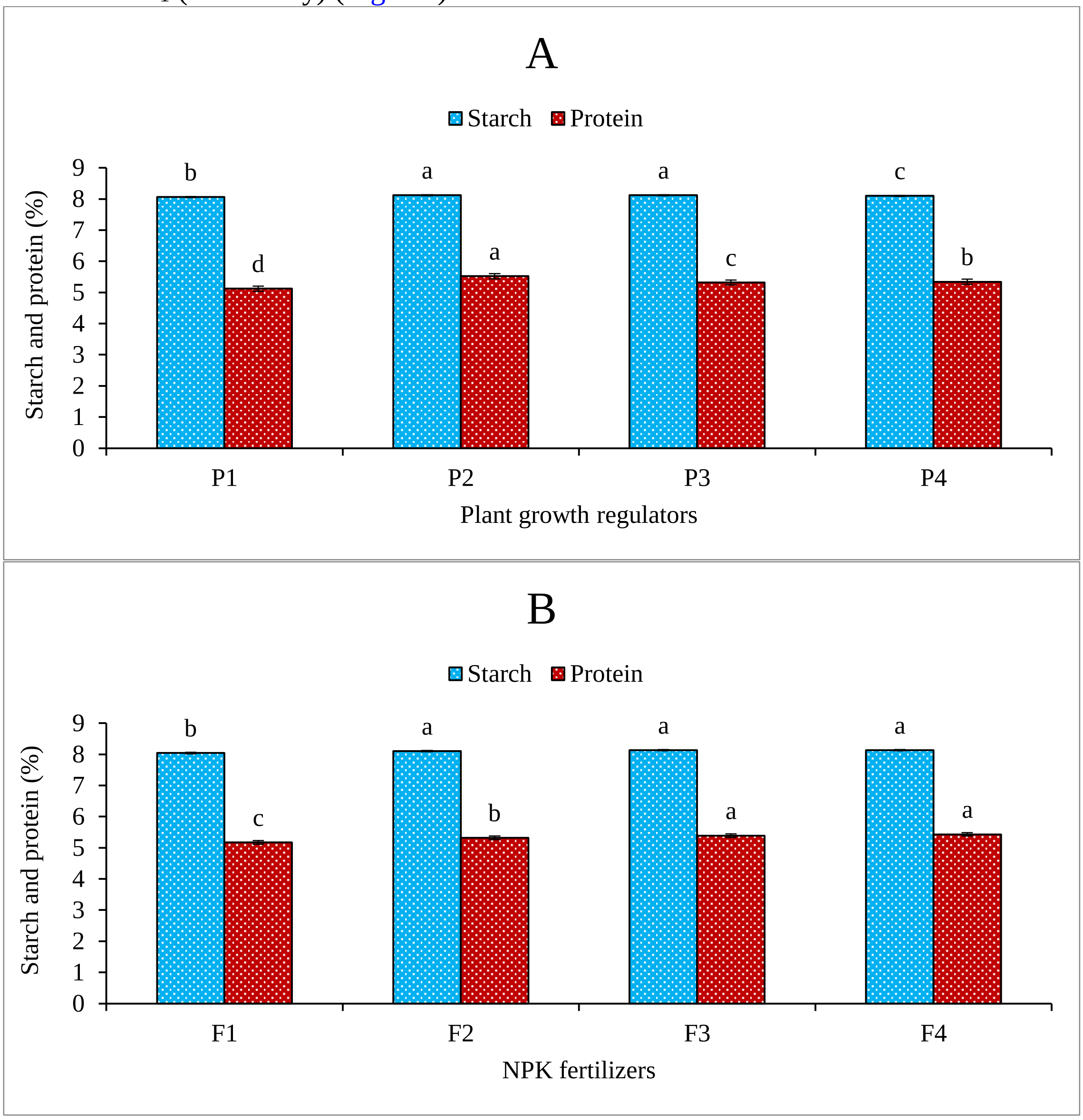

Fig. 6. Impact of PGRs (A) and NPK fertilizer (B) on baby corn quality attributes.

Table 5. Interaction effects of plant growth regulators and NPK fertilizer on yield attributes and yield of baby corn.

Plant growth regulators: NPK fertilizer	Number of cob plant^{-1}	Fresh weight plant^{-1} (g)	Dry weight plant^{-1} (g)	Cob length with husk (cm)	Cob length without husk (cm)	Cob diameter with husk (cm)
P1:F1	2.00c	100.11ab	61.22ab	16.39g	11.55f	2.39f
P1:F2	2.67a-c	110.33ab	71.22ab	17.44fg	14.06b-e	2.54ef
P1:F3	2.67a-c	109.78ab	66.18ab	17.50fg	13.67c-f	2.88c-e
P1:F4	3.00a-c	74.11c	43.78b	19.17d-f	14.05b-e	2.86c-e
P2:F1	2.67a-c	83.33b	43.11b	20.11c-e	13.61c-f	2.81de
P2:F2	2.67a-c	90.55b	52.22b	22.05a-c	15.83a-c	3.20a-c
P2:F3	3.67a	99.11ab	78.44ab	22.00a-c	16.33ab	3.25ab
P2:F4	3.67a	82.99b	65.56ab	22.89ab	17.17a	3.27ab
P3:F1	2.33bc	83.22b	55.44ab	18.44ef	12.28ef	2.96b-d
P3:F2	3.00a-c	88.11b	57.11ab	18.78ef	14.17b-e	3.22a-c
P3:F3	3.00a-c	84.89b	51.00ab	18.94ef	14.17b-e	3.04b-d
P3:F4	3.33ab	123.33a	81.44ab	21.39a-c	15.67a-c	3.44a
P4:F1	2.67a-c	125.67a	70.44ab	20.89b-d	12.83d-f	3.13a-d
P4:F2	3.00a-c	109.01ab	33.89b	21.17a-c	12.39ef	3.26ab
P4:F3	3.67a	109.89ab	103.67a	21.69a-c	14.55b-e	3.42a
P4:F4	3.67a	94.67b	53.67b	23.11a	15.22a-d	3.46a
S$\bar{x}$	0.13	3.84	4.28	0.52	0.39	0.08
Level of significance	*	*	*	*	*	*
CV (%)	10.40	8.80	5.40	5.20	8.70	6.40

The means that have the same letters are not substantially different, * = Significant at 5 % level of probability, P_1=Water only, P_2=Mepiquat chloride 200 ppm, P_3=Naphthalene acetic acid (NAA) 40 ppm, P_4=Gibberellic Acid (GA_3) 100 ppm, F_1=150-90-75 kg ha^{-1}, F_2=180-105-90 kg ha^{-1}, F_3=210-120-105 kg ha^{-1}, F_4=240-135-120 kg ha^{-1}.

Table 5. (***Continued***). Interaction effects of plant growth regulators and NPK fertilizer on yield attributes and yield of baby corn.

Plant growth regulators: NPK fertilizer	Cob diameter without husk (cm)	Cob weight with husk (g)	Cob weight without husk (g)	Cob yield with husk (t ha^{-1})	Cob yield without husk (t ha^{-1})	Green fodder yield (t ha^{-1})
P1:F1	2.09g	66.90f	33.45f	5.75b	2.87e	22.63ef
P1:F2	2.41d-f	72.58ef	38.48ef	6.07ab	3.08e	24.70b-d
P1:F3	2.36ef	77.89d-f	41.93de	6.79ab	3.42c-e	24.38c-e
P1:F4	2.51c-f	81.97b-e	43.21c-e	6.72ab	3.42c-e	23.93d-f
P2:F1	2.27fg	80.33c-e	38.67ef	6.80ab	3.16de	22.34f
P2:F2	2.60b-e	88.22a-d	48.02a-d	7.06ab	3.84a-d	23.65d-f
P2:F3	2.67b-d	91.00a-d	51.42a-c	7.28a	4.11a-c	23.80d-f
P2:F4	2.74a-c	94.73ab	51.32a-c	7.21a	4.04a-c	23.17d-f
P3:F1	2.37ef	77.30d-f	42.09de	6.67ab	3.41c-e	26.13a-c
P3:F2	2.63b-e	87.34a-d	48.85a-d	6.99ab	3.91a-c	26.70a
P3:F3	2.59c-e	88.45a-d	47.48a-d	7.08ab	3.80a-d	26.73a
P3:F4	2.77a-c	94.05a-c	52.29ab	7.10ab	4.17ab	26.53ab
P4:F1	2.45d-f	81.90b-e	44.51b-e	6.82ab	3.55b-e	24.80b-d
P4:F2	2.74a-c	94.03a-c	50.72a-d	7.26a	4.06a-c	26.07a-c
P4:F3	2.88ab	97.04a	53.69a	7.31a	4.07a-c	26.35ab
P4:F4	2.95a	98.48a	55.29a	7.05ab	4.41a	26.22ab
S$\bar{x}$	0.06	2.3	1.56	0.11	0.11	0.38
Level of significance	*	*	*	*	*	*
CV (%)	5.80	8.30	10.00	10.40	9.90	3.90

Effect of NPK fertilizer level

Starch (%) contents were significantly affected by the NPK fertilizer. The highest starch (8.13%) was recorded with F_4 (240-135-120 kg ha^{-1}) which was statistically similar with F_2 (180-105-90 kg ha^{-1}) and F_3 (210-120-105 kg ha^{-1}). The lowest starch (8.04%) was recorded with F_1 (150-90-75 kg ha^{-1}) (Fig. 6B). NPK fertilizer had significant effect on protein content. The higher values of protein % (5.43) was obtained with F_4 (240-135-120 kg ha^{-1}) and the lowest value (5.17) was recorded with F_1 (180-105-90 kg ha^{-1}) (Fig. 6B).

Impact of PGRs and NPK fertilizer levels work together on quality aspects

The interaction of PGRs and NPK fertilizer levels on starch had significant differences. The highest starch content (8.15) was recorded in interaction of Mepiquat chloride 200 ppm × 240-135-120 kg ha^{-1} which is statistically similar with Naphthalene Acetic Acid (NAA) 40 ppm × 210-120-105 kg ha^{-1}. The lowest starch content (7.96) was recorded in interaction of water only × 150-90-75 kg ha^{-1} (Table 6). The interaction of PGRs and NPK fertilizer levels on protein content had significant differences. The highest protein content (5.56) was recorded in interaction Mepiquat chloride 200 ppm × 210-120-105 kg ha^{-1} which is statistically similar with Mepiquat chloride 200 ppm × 210-120-105 kg ha^{-1}. The lowest protein content (4.94) was recorded in interaction of water only ×150-90-75 kg ha^{-1} (Table 6).

Table 6. Interaction effects of plant growth regulators and NPK fertilizer on quality of baby corn.

Plant growth regulators: NPK fertilizer	Starch (%)	Protein (%)
P1:F1	7.96d	4.94e
P1:F2	8.05c	5.01e
P1:F3	8.10a-c	5.17d
P1:F4	8.12a-c	5.37bc
P2:F1	8.07a-c	5.43b
P2:F2	8.13a-c	5.56a
P2:F3	8.15a	5.56a
P2:F4	8.15a	5.53a
P3:F1	8.06a-c	5.13d
P3:F2	8.12a-c	5.33c
P3:F3	8.15a	5.40bc
P3:F4	8.14ab	5.41b
P4:F1	8.05bc	5.17d
P4:F2	8.10a-c	5.39bc
P4:F3	8.13ab	5.42b
P4:F4	8.12a-c	5.40bc
$S\bar{x}$	0.01	0.05
Level of significance	*	**
CV (%)	0.60	0.80

The means that have the same letters are not substantially different, * = Significant at 5 % level of probability, ** = Significant at 1% level of probability, P_1=Water only, P_2=Mepiquat chloride 200 ppm, P_3=Naphthalene acetic acid (NAA) 40 ppm, P_4=Gibberellic Acid (GA_3) 100 ppm, F_1=150-90-75 kg ha^{-1}, F_2=180-105-90 kg ha^{-1}, F_3=210-120-105 kg ha^{-1}, F_4=240-135-120 kg ha^{-1}.

PC, correlation and heatmap analysis

Principal Component Analysis was used to determine the traits that best describe the optimizing baby corn growth, yield and quality with plant growth regulator (PGR). Figure 7 shows the bi-plot of the first two principal components along with the variable loadings. First principal component (PC1), which accounts for 53.5% of the total variance, is shown by the x-axis; second principal component (PC2), which accounts for 20.8% of the total variance, is represented by the y-axis.

Leaf number, chlorophyll content, leaf width, leaf length, cob diameter without husk, shoot dry weight, cob diameter with husk, root dry weight, cob weight without husk, cob yield with husk, cob weight with husk, cob plant^{-1}, cob yield without husk, variables have a strong positive correlation with PC1.Plant height, green fodder yield, fresh weight plant^{-1}, protein, starch, and cob weight without husk were more aligned with PCA2. Leaf number, leaf width, leaf length, chlorophyll content, cob diameter without husk, cob diameter with husk, cob weight without husk, cob weight with husk, cob yield with husk, cob yield without husk, cob plant^{-1}, shoot dry weight are closely aligned, indicating a strong positive correlation with each other. Plant height, green fodder yield, fresh weight plant^{-1} were cluster with each other that means they strong positive correlation with each other. Protein, starch, and cob weight without husk were cluster with each other that means them strong positive correlation with each other. Plant height, green fodder yield, fresh weight plant^{-1} has no correlation with Protein, starch, and cob weight without husk. Treatment 2 is strongly influenced by PC2 and is distinct from other observations and treatments 3 is strongly influenced by PC1 and is distinct from other observations while treatment 4 is closer to the origin, indicating it has more average values for the principal components.

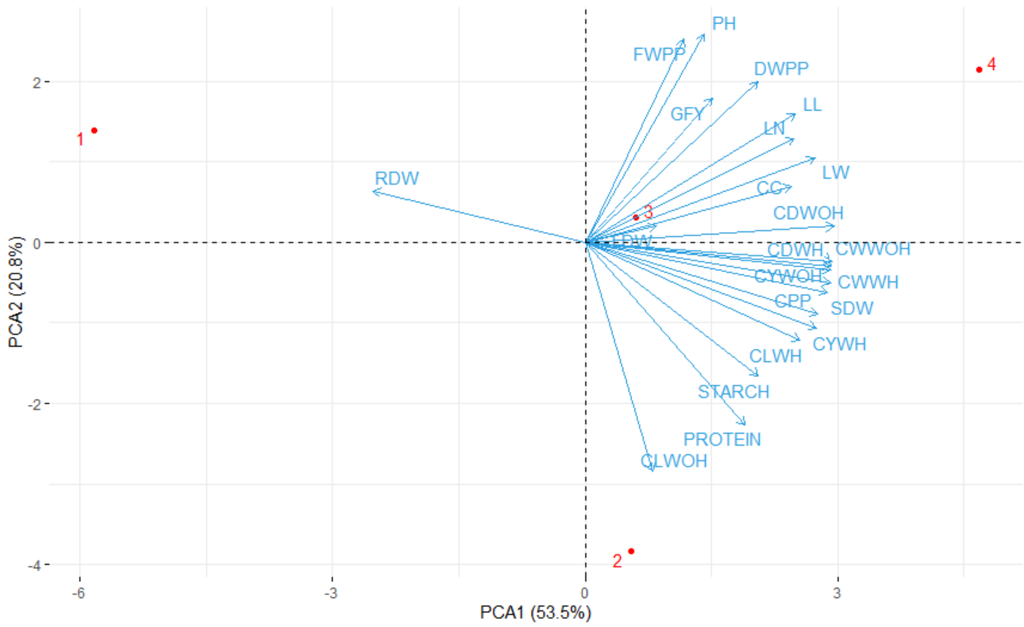

Fig. 7. Principal component analysis biplot (PCA) displaying the initial two principal components (PC 1 and PC 2). For PCA, data on growth, yield and yield contributing attributes under plant growth regulator (PGR). The red dots are indicating five PGR treatments, like 1 = No plant growth regulator (Water only), 2 = Mepiquat chloride 200 ppm, 3 = Naphthalene acetic acid (NAA) 40 ppm, 4 = Gibberellic acid (GA_3) 100 ppm. Where PH= Plant height (cm), LN= leaf number, LL= leaf length, LW= leaf width, CC= Chlorophyll content, LDW= leaf dry weight, RDW= root dry weight, SDW= shoot dry weight, CPP= cob plant^{-1}, CLWH= cob length with husk, CLWOH= cob length without husk, CWWH= cob weight with husk, CWWOH= cob weight without husk, CDWH= cob diameter with husk, CDWOH= cob diameter without husk, FWPP= fresh weight plant^{-1}, DWPP= dry weight plant^{-1}, CYWH= cob yield with husk, CYWOH= cob yield without husk, GFY= green fodder yield.

Principal Component Analysis was used to determine the the optimizing baby corn growth, yield and quality with NPK fertilizer. Figure 8 displays the loadings of variables as well as the bi-plot of the first two main components.

The first principal component (PC1), which makes up 62.4% of the total variance, is represented by the x-axis, and the second main component (PC2), which makes up 16% of the variance, is represented by the y-axis.

Plant height, leaf number, cob plant^{-1}, cob weight without husk, cob weight with husk, protein, cob diameter without husk, starch, cob diameter with husk, cob length without husk, chlorophyll content, cob yield with husk, and cob yield without husk variables have a strong positive correlation with PC1. Leaf length, leaf width, cob length with husk, fresh weight plant^{-1} has a strong positive correlation with PC2. Plant height, cob plant^{-1}, cob weight without husk, leaf number, cob weight with husk, chlorophyll content, cob diameter without husk, protein, cob diameter with husk, cob length without husk, starch, cob yield without husk, and cob yield with husk variables are closely aligned, indicating a strong positive correlation with each other. Leaf length, leaf width, cob length with husk variables is closely aligned, indicating a strong positive correlation with each other and negatively correlated with the other group of variables. Treatment 2 is strongly influenced by PC2 and is distinct from other observations and treatment 1 is strongly influenced by PC1 and is distinct from other observations while treatment 3 and 4 are closer to the origin, indicating they have more average values for the principal components.

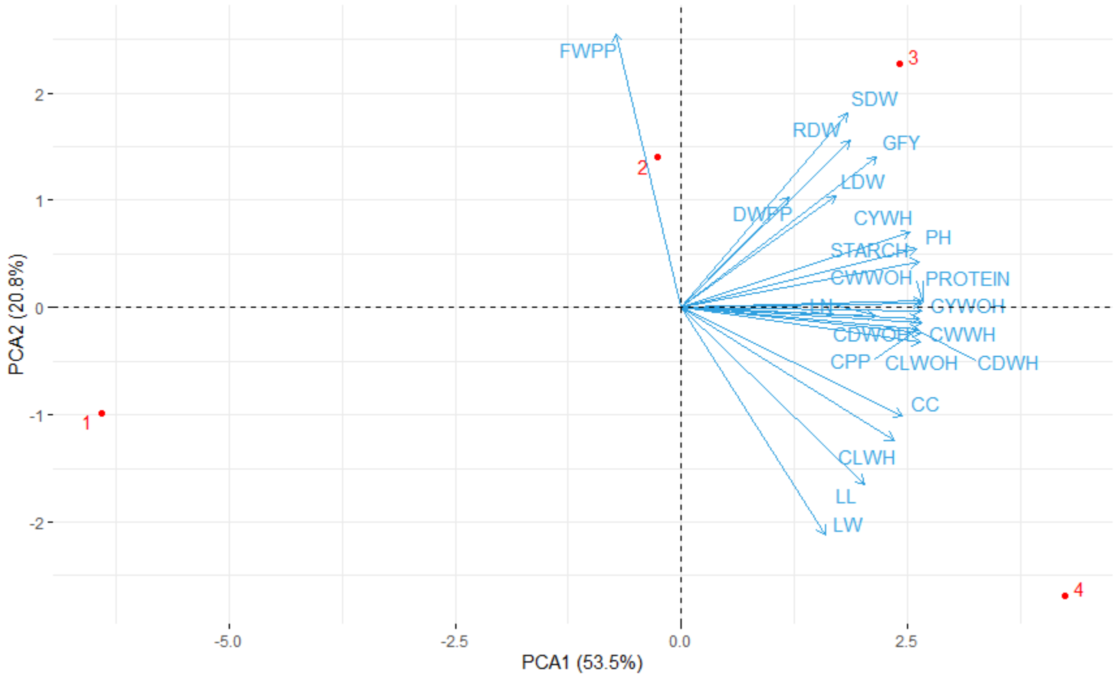

Fig. 8. Principal component analysis biplot (PCA) displaying the initial two principal components (PC 1 and PC 2). For PCA, data on growth yield and yield contributing attributes under NPK fertilizer. The red dots are indicating five NPK treatments. Where, PH= Plant height (cm), LN= leaf number, LL= leaf length, LW= leaf width, CC= Chlorophyll content, LDW= leaf dry weight, RDW= root dry weight, SDW= shoot dry weight, CPP= cob plant^{-1}, CLWH= cob length with husk, CLWOH= cob length without husk, CWWH= cob weight with husk, CWWOH= cob weight without husk, CDWH= cob diameter with husk, CDWOH= cob diameter without husk, FWPP= fresh weight plant^{-1}, DWPP= dry weight plant^{-1}, CYWH= cob yield with husk, CYWOH= cob yield without husk, GFY= green fodder yield.

A correlation was performed to identify the interrelationship between different growth and yield traits, as well as weed growth at various stages, under four treatments comprised by the optimizing baby corn growth, yield and quality with plant growth regulator (PGR) (Fig. 9). The analysis revealed that the cob yield without husk had a strong positive correlation (<0.001) with cob diameter with husk and moderately correlation with cob weight without husk (P<0.01) while with cob yield with husk and cob diameter without husk was normally corelated at P<0.05. Cob diameter with husk had a strong positive correlation with cob weight without husk and maintained a positive correlation with cob yield with husk and cob diameter without husk. Cob weight without husk showed a positive correlation with cob yield with husk and cob diameter without husk. Shoot dry weight presented a moderately positive correlation with cob yield without husk and cob diameter with husk and correlation with cob yield with husk, cob diameter without husk and cob plant^{-1}**.** Cob weight with husk highlighted a moderately correlation with cob yield without husk, shoot dry weight, cob weight without husk, cob diameter with husk, and it was corelated with cob diameter with husk, cob yield with husk, and cob plant^{-1}.

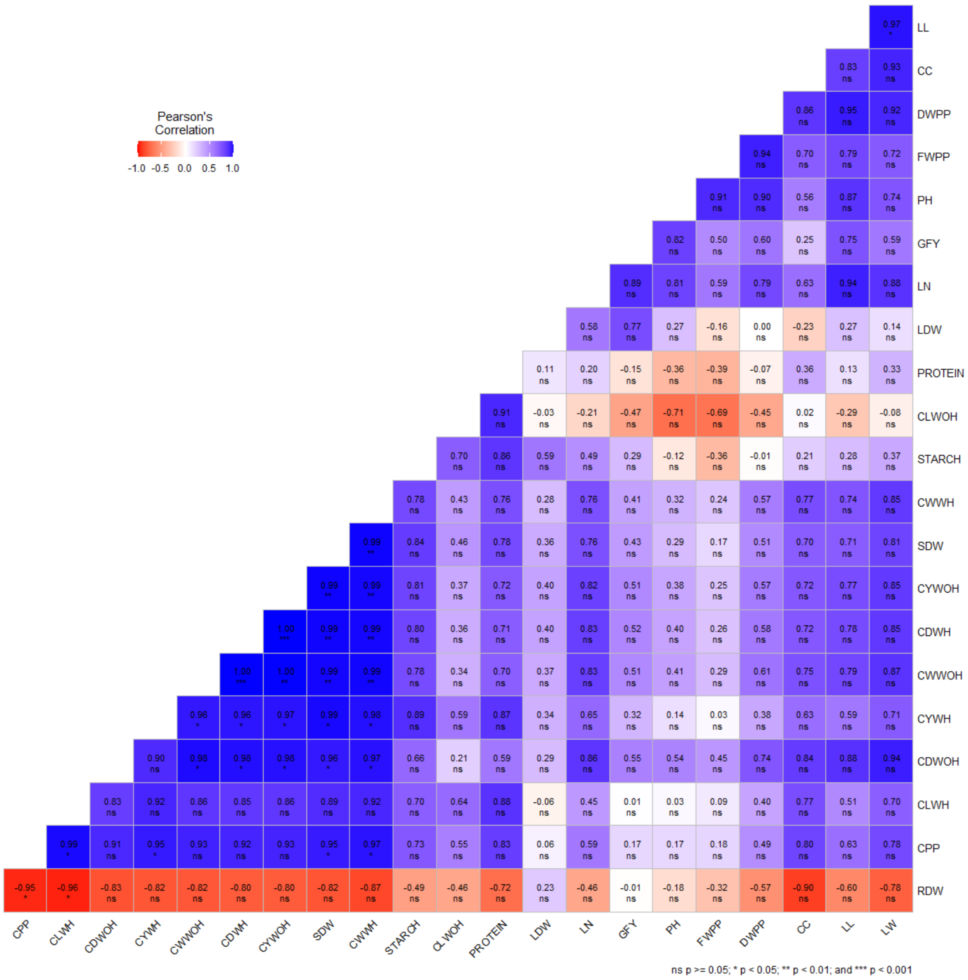

Fig. 9. Pearson correlation analysis of optimizing baby corn growth, yield and quality with plant growth regulator (PGR). ***, **, * and NS (Not Significant) represent probability of ≤0.001, ≤0.01, ≤0.05 and >0.05, respectively. Where, PH= Plant height (cm), LN= leaf number, LL= leaf length, LW= leaf width, CC= Chlorophyll content, LDW= leaf dry weight, RDW= root dry weight, SDW= shoot dry weight, CPP= cob plant^{-1}, CLWH= cob length with husk, CLWOH= cob length without husk, CWWH= cob weight with husk, CWWOH= cob weight without husk, CDWH= cob diameter with husk, CDWOH= cob diameter without husk, FWPP= fresh weight plant^{-1}, DWPP= dry weight plant^{-1}, CYWH= cob yield with husk, CYWOH= cob yield without husk, GFY= green fodder yield.

A correlation was performed to identify the interrelationship between different growth and yield traits, as well as weed growth at various stages, under four treatments comprised by the optimizing baby corn growth, yield and quality with NPK fertilizer (Fig. 10). The analysis revealed that the cob yield without husk (P<0.001) with cob weight without husk and moderately correlation with cob diameter with husk, protein, cob diameter without husk, cob weight with husk and cob length without husk (P<0.01) while with plant height, cob plant^{-1}, and starch was normally corelated at P<0.05. Cob weight without husk had a moderately positive correlation with protein, cob diameter with husk, cob diameter without husk and corelated with plant height, cob plant^{-1}, starch, and cob length without husk. Protein represented a moderately positive correlation with cob diameter with husk, cob length without husk, cob weight with husk and corelated with cob diameter without husk, plant height, cob plant^{-1}, cob yield with husk starch. Cob diameter with husk had a strong positive correlation with cob length without husk and moderately correlation with cob weight with husk and corelated with cob diameter without husk, plant height, cob plant^{-1}, starch. Cob length without husk showed a moderately positive correlation with cob weight with husk and corelated with cob diameter without husk, starch, cob plant^{-1}. Cob weight with husk highlighted a moderately positive correlation with cob diameter without husk and maintained a positive correlation with plant height, cob plant^{-1}, starch. Plant height showed a moderately positive correlation with starch.

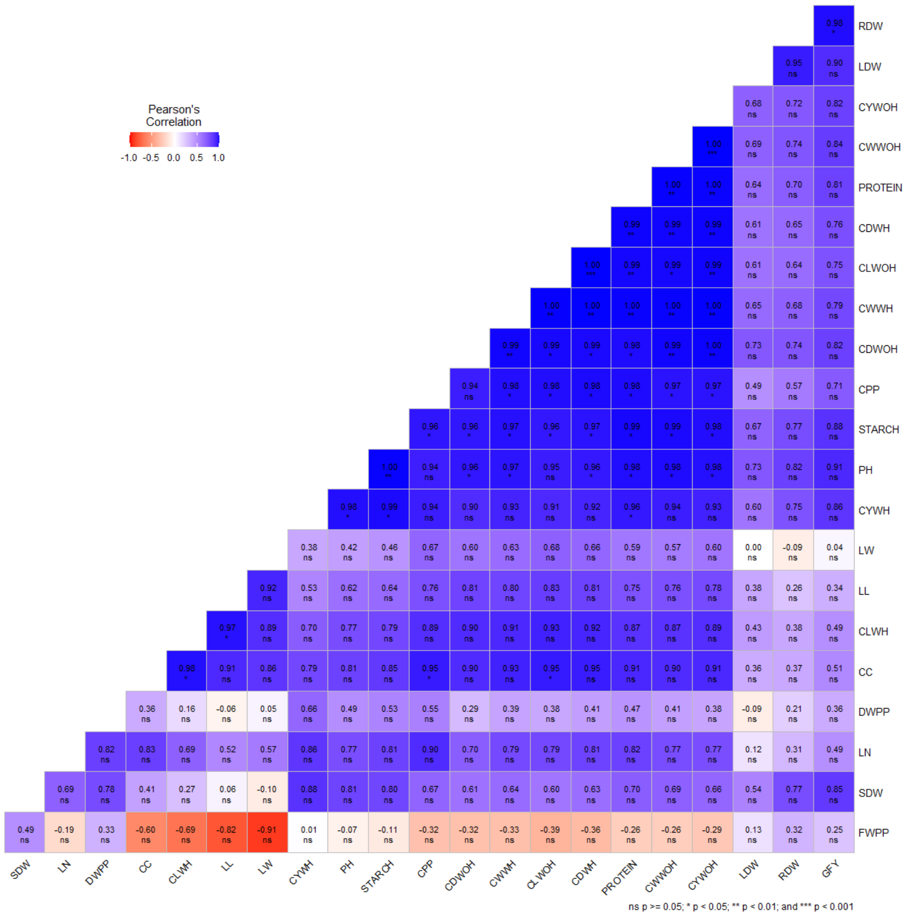

Fig. 10. Pearson correlation analysis of optimizing baby corn growth, yield and quality with NPK fertilizer. ∗∗∗, ∗∗, ∗ and NS (Not Significant) represent probability of ≤0.001, ≤0.01, ≤0.05 and >0.05, respectively. Where, PH= Plant height (cm), LN= leaf number, LL= leaf length, LW= leaf width, CC= Chlorophyll content, LDW= leaf dry weight, RDW= root dry weight, SDW= shoot dry weight, CPP= cob plant^{-1}, CLWH= cob length with husk, CLWOH= cob length without husk, CWWH= cob weight with husk, CWWOH= cob weight without husk, CDWH= cob diameter with husk, CDWOH= cob diameter without husk, FWPP= fresh weight plant^{-1}, DWPP= dry weight plant^{-1}, CYWH= cob yield with husk, CYWOH= cob yield without husk, GFY= green fodder yield.

So, this study revealed that plant growth regulator (PGR) and NPK fertilizers had a positive impact on the corn growth, yield and quality performance of baby corn.

A heat map was used to analyze the traits that best demonstrate the optimizing baby corn growth, yield and quality with plant growth regulator (PGR) and NPK fertilizer. The x-axis represents the variables related to growth, yield and yield contributing variable while the y-axis represents the different plant growth regulator treatments (Fig. 11). Leaf width, cob weight with husk, stem dry weight, cob yield without husk, fresh weight, cob diameter with husk, plant height, cob weight without husk, leaf length, leaf number, cob yield with husk, chlorophyll content, cob diameter without husk, root dry weight, cob length with husk, dry weight, cob plant^{-1} variables had a high contribution with P_4 (Gibberellic Acid (GA_3) 100 ppm) treatment. Leaf width, cob weight with husk, stem dry weight, cob yield without husk, leaf length, cob diameter with husk, protein, cob weight without husk, starch, cob yield with husk, chlorophyll content, cob diameter without husk, cob length with husk, leaf number, and cob plant^{-1} variables represented the lowest contribution with P_1 (water only) treatment. Other treatments-maintained light, moderate, and neutral relationships among all the parameters.

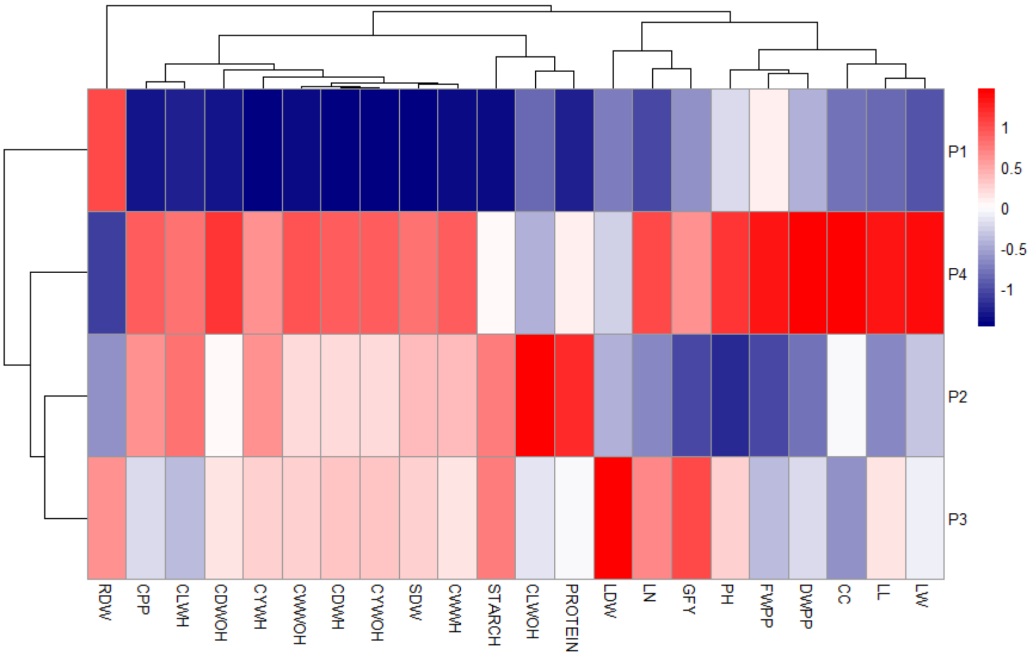

Fig. 11. Heat map analysis of the impact of optimizing baby corn growth, yield and quality with plant growth regulator (PGR). Where, PH= Plant height (cm), LN= leaf number, LL= leaf length, LW= leaf width, CC= Chlorophyll content, LDW= leaf dry weight, RDW= root dry weight, SDW= shoot dry weight, CPP= cob plant^{-1}, CLWH= cob length with husk, CLWOH= cob length without husk, CWWH= cob weight with husk, CWWOH= cob weight without husk, CDWH= cob diameter with husk, CDWOH= cob diameter without husk, FWPP= fresh weight plant^{-1}, DWPP= dry weight plant^{-1}, CYWH= cob yield with husk, CYWOH= cob yield without husk, GFY= green fodder yield.

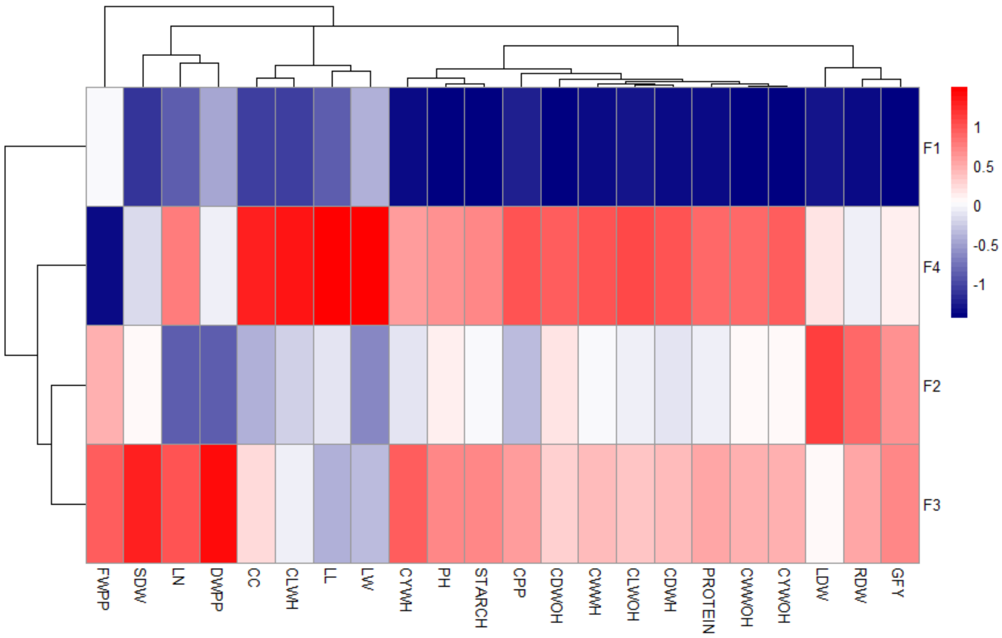

Fig. 12. Heat map analysis of the impact of optimizing baby corn growth, yield and quality with NPK fertilizer. Where, PH= Plant height (cm), LN= leaf number, LL= leaf length, LW= leaf width, CC= Chlorophyll content, LDW= leaf dry weight, RDW= root dry weight, SDW= shoot dry weight, CPP= cob plant^{-1}, CLWH= cob length with husk, CLWOH= cob length without husk, CWWH= cob weight with husk, CWWOH= cob weight without husk, CDWH= cob diameter with husk, CDWOH= cob diameter without husk, FWPP= fresh weight plant^{-1}, DWPP= dry weight plant^{-1}, CYWH= cob yield with husk, CYWOH= cob yield without husk, GFY= green fodder yield.

A heat map was used to analyze the traits that best demonstrate the optimizing baby corn growth, yield and quality with plant growth regulator (PGR) and NPK fertilizer. The x-axis represents the variables related to growth, yield and yield contributing variable while the y-axis represents the different NPK treatments (Fig. 12). Chlorophyll content, cob length with husk, leaf number, cob yield with husk, starch, cob plant^{-1}, cob diameter without husk, leaf length, cob weight with husk, leaf width, cob length without husk, cob diameter with husk, protein, cob weight without husk, plant height, and cob yield without husk variables had a high contribution with F_4 (240-135-120 kg ha^{-1}) treatment. Green fodder yield, cob yield without husk, starch, cob weight without husk, protein, cob diameter with husk, leaf length, cob length without husk, root dry weight, cob plant^{-1}, plant height, cob yield with husk, leaf dry weight, cob length with husk, chlorophyll content, leaf number, and shoot dry weight variables represented the lowest contribution with F_1 (150-90-75 kg ha^{-1}) treatment. Other treatments-maintained light, moderate, and neutral relationships among all the parameters.

DISCUSSION

Impact of PGRs and NPK fertilizer levels on the growth of baby corn

An investigation by Golada et al. (2013) revealed that higher values of growth statistics were reported with NAA at 40 ppm. Corn grows much faster when GA3 is sprayed on its leaves, according to Wen et al. (2010). Muthukumar et al. (2005) observed similar findings. NAA promotes vegetative growth, stimulates reproductive growth and significantly enhances the fodder yield of baby corn (Rao et al., 2021; Muthukumar et al., 2005). Singh et al. (2018) observed more leaf length and better silking with spraying of gibberellic acid. Maher et al. (2018) observed a high synthesis of antioxidant chemicals and corn silk. Suo et al. (2017) noticed improved seed germination and better seedlings appearance with the application of hormone GA_3. Singh et al. (2014) observed taller plant height and better silking in maize with the application of gibberellic acid. Mahdi et al. (2012) investigated the impacts of different nitrogen levels 60, 90, and 120 kg N ha^{-1} on the growth components of fodder maize in Shalimar (JK). They found that, at 120 kg N ha^{-1}, leaf area index and plant height increased significantly. Similar results were found by Jeet (2013) in Varanasi, where higher amounts of nitrogen delivery up to 150 kg N ha^{-1} were associated with noticeably taller plants, wider stem girth, more green leaves, dry weight, and leaf area index crop growth rate.

PGRs and NPK fertilizer levels interact and influence the yield and characteristics related to yield of baby corn

Gibberellic acid application resulted in higher yield qualities, such as cobs $plant^{-1}$, cobs length, grains cob^{-1}, and weight of cobs, according to Singh et al. (2018). According to Golada et al. (2013), higher cell division, enlargement, and elongation resulted from NAA management, which greatly increased the fodder output. Amanullah et al. (2010); Rathika et al. (2009) provided findings that were comparable.

Application of NAA helps in higher fodder yield production of baby corn (Lal et al., 2024; Muthukumar et al., 2005). Plant height, dry matter production, and ultimately fodder output is all decreased by the growth retardant mepiquat chloride (Gao et al., 2019). Gibberellic acid inhibitor mepiquat chloride (MC) reduces cell elongation and restricts plant expansion (Wu et al., 2023). To inhibit excessive germination rate, enhance root development, and minimize yield reduction, Mepiquat chloride (MC) is commonly used in cotton production (Chen et al., 2018). According to research conducted by Singh et al. (2016), the application of 5t FYM + 100 kg N ha^{-1}, followed by the 100% recommended dose of nitrogen, produced the highest baby corn yield, baby corn length, baby corn girth, number of cobs, baby cob weight, and baby corn weight. When increasing the amount of nitrogen 150 kg N ha^{-1}, Verma et al. (2012) found that working with maize at Hamirpur (UP) boosted cob diameter, cob weight, and grain production significantly. Grain yields were 2.3% and 7.4% higher at the maximum nitrogen application amount of 150 kg N ha^{-1} compared to 100 and 50 N ha^{-1}, respectively (Qadeer et al., 2019).

Impact of PGRs and NPK fertilizer levels on the quality aspects of baby corn

The application of mepiquat chloride at a concentration of 200 ppm has been reported to increase the starch content in maize. According to a study conducted by Zhang et al. (2020), the application of mepiquat chloride at 200 ppm increased the starch content in maize by 3.6% compared to the control group. Similarly, another study by Al-Khafaji et al. (2021) reported that the application of mepiquat chloride at 200 ppm increased the starch content by 4.2% compared to the control group. A study by Sing et al. (2018) reported that the application of mepiquat chloride at 200 ppm increased the protein content in maize by 3.7% compared to the control group. Similarly, a study by Reddy et al. (2021) reported that the application of mepiquat chloride at 200 ppm increased the protein content by 4.5% compared to the control group. These findings suggest that mepiquat chloride at 200 ppm can potentially enhance the protein content in maize. Mahdi et al. (2012) discovered that applying 120 kg N ha^{-1} effectively increased crude protein, protein production, and crude fiber content compared to 90 kg N ha^{-1}. As nitrogen levels increased up to 300 kg N ha^{-1}, Khan et al. (2011) found that maize grain's protein content increased equally. According to Carpici et al. (2010), applying 400 kg N ha^{-1} resulted in noticeably greater crude protein content.

CONCLUSION

In this agroclimatic zone, applying 240-135-120 kg NPK ha^{-1} together with foliar spraying 100 ppm of gibberellic acid is thought to be beneficial for achieving higher growth, yield, and quality of baby corn, according to the results of a field experiment titled "Optimizing baby corn growth, yield and quality with plant growth regulator (PGR) and NPK fertilizer." In this agroclimatic zone, farmers may be able to increase their income by adopting these strategies.

Conflict of interest

The authors have no conflict of interest to report.

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